January 22, 2003

Experiment 1 – Evaluation of Raman lidar, MPL lidar aerosol backscatter, extinction profiles

Objective(s):

a) evaluate aerosol extinction profiles retrieved by Raman and MPL lidars, airborne Sun photometer, and derived from in situ aerosol scattering, absorption, extinction sensors on aircraft
b) evaluate near field overlap correction on both Raman lidar and MPL systems
c) evaluate assumption of constant aerosol extinction/backscatter ratio in lowest kilometer used in Raman lidar aerosol extinction profile retrievals
d) evaluation of vertical variability of aerosol humidification factor
e) closure study f(RH) from lidar vs. f(RH) from surface PCASP, composition, and calculated enhancement of extinction or backscatter

Advocate(s): Ferrare, Schmid, Redemann, Feingold

Measurement strategy: Use Twin Otter flights at various altitudes over the SGP facility so that in situ and remote (Sun photometer) instruments on Twin Otter can measure aerosol extinction, scattering, absorption simultaneously with ground-based lidar and surface AOS measurements. Skies should be cloud free or with scattered small Cumulus clouds so that the Sun photometer instruments can measure aerosol optical thickness. Small patchy cirrus clouds are acceptable as long as these clouds do not adversely affect Sun photometer measurements of aerosol optical thickness. Since the Raman lidar profiles are most sensitive to high aerosol optical thickness conditions, these flights should occur during the daytime when aerosol optical thickness (355 nm) is above 0.15-0.20. The Raman lidar directly measures aerosol extinction for altitudes above about 800 meters; therefore, in order to directly evaluate Raman lidar boundary layer aerosol extinction profiles, flights are preferred when the boundary layer thickness, z_i, is above 1.0 to 1.2 km. Estimated takeoff time would be around 11 am CDT (16 UT). A radiosonde is normally launched from the SGP site at 1730 UT (12:30 CDT). It would be desirable to launch a sonde at the beginning of the flight (~16 UT) and at the end also (~19-20 UT).

Critical Instruments: Raman lidar, MPL, AOS scattering/absorption, Cimel Sun photometer, MFRSR, Twin Otter scattering/absorption/extinction measurements

Relevant Instruments/Measurements (See table 1): 1-13, 17, 20-26, 27-35, 53

Flight Strategy 1a (fast extinction closure):

This flight pattern would be used when there would be little or no cloud interference with the Sun photometer measurements. The flight would utilize two spirals to get aerosol extinction and optical thickness profiles from the Sun photometer. The Twin Otter (TO) will takeoff from Ponca City and transit to the SGP vicinity. (~30 min) TO would then perform a fast (clockwise or counterclockwise) spiral (~ at about 500 feet/min) over the SGP site, starting at 300 feet and ending at 10000 feet to facilitate Sun photometer measurements of aerosol optical thickness. Spiral diameter would be about 1 km in diameter. After this spiral, the TO will then perform a series of level leg flights at several altitudes oriented generally 10-20 deg from the mean wind direction in order to avoid aircraft exhaust. These level legs are centered at the SGP site. These flight legs will start at 10000 feet (AGL), with legs at 7000 ft (10 min), 5000 ft (10 min), 4000 ft (5 min), 3500 ft (5 min), 3000 ft (5 min), 2000 ft (5 min), 1000 ft (5 min), and 300 ft (5 min). Estimated time for descending turns between legs is 2-3 min. The aircraft will then repeat this fast spiral ascent followed by level leg descent pattern. During the leg level descent pattern, the leg at 7000 ft could be replaced by other altitude(s) if the TO scientist notes significant aerosol loading associated with elevated aerosol layers at other altitudes. The leg at 3500 ft or 4000 ft could be replaced by a leg at/near the top of the boundary layer where the TO scientist noted high aerosol scattering associated with high relative humidity. After completing this portion, the aircraft will return to base on Ponca City. Total flight time is estimated to be 04:20. If the Vance MOA prevents the flight leg orientation described above, then the orientations of the legs, and the position at which the aircraft passes over the SGP could be adjusted. Twin Otter flight speed is about 100 knots (~ 3 km/min) so that the 5 (10) minute legs would be about 15 km (30 km) long.

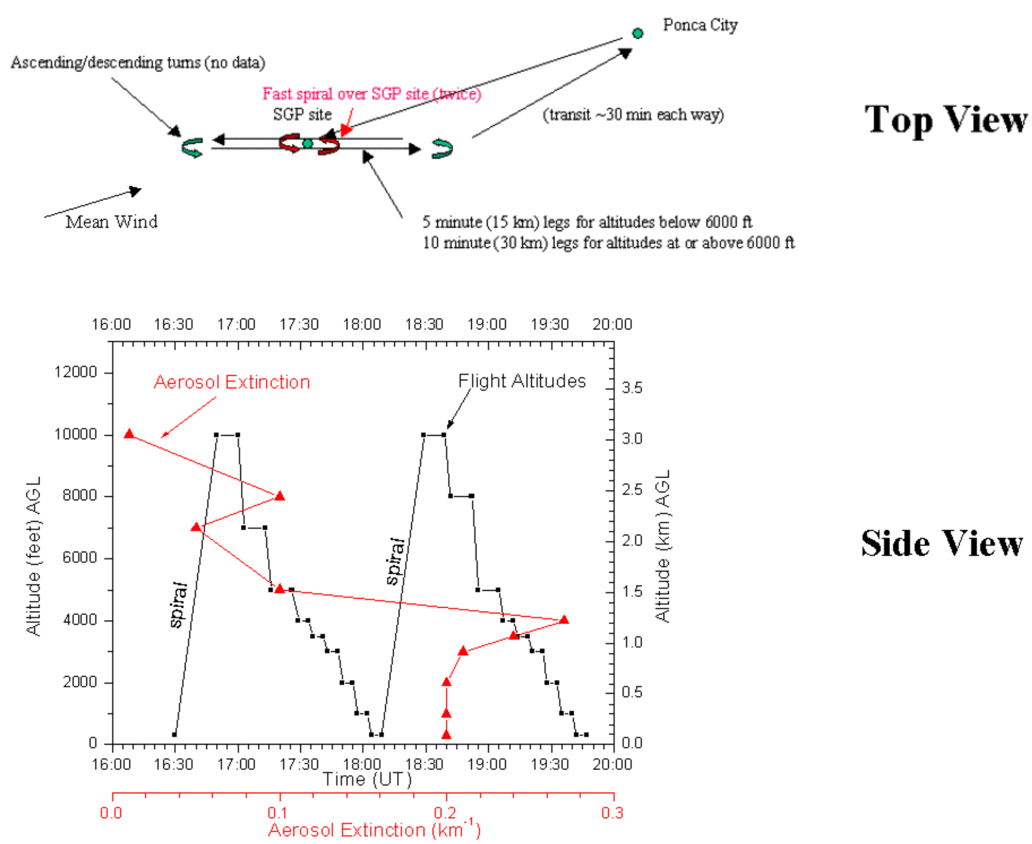

Figure 1a. Top and side views of flight plan 1a.

Flight Strategy 1b (slow extinction closure):

This flight pattern would be used when clouds would be expected to interefere with the Sun photometer measurements. The Twin Otter will takeoff from Ponca City and transit to the SGP vicinity. (~30 min) TO will then perform a series of level leg flights at several altitudes oriented 10-20 deg from the mean wind direction to avoid aircraft exhaust. These level legs are centered at the SGP site. These flight legs will start at 300 feet (AGL), and proceed to 1000 ft (5 min), 2000 ft (5 min), 3000 ft (5 min), 3500 ft (5 min), 4000 ft (5 min), 5000 ft (10 min), 7000 ft (10 min), 100000 ft (10 min). Estimated time for climbing turns between legs is 2-3 min. The aircraft will then perform a series of level legs during a descent. In this case, there would be fewer level legs, with each leg of longer duration (~20 minutes) to facilitate the MOUDI in situ aerosol sampling. These level legs would be performed at altitudes with significant aerosol loading as noted by the TO scientist/operator. For example, the leg at 7000 ft would be replaced by a (longer) leg at 8000 ft if the TO scientist/operator noted significant aerosol loading associated with an elevated aerosol layer at this altitude. Likewise, the leg at 3500 ft or 4000 ft could be replaced by a leg at/near the top of the boundary layer where the TO scientist noted high aerosol scattering associated with high relative humidity. After completing this portion, the aircraft will return to base on Ponca City. Total flight time is estimated to be 04:00. If the Vance MOA prevents flights along the orientation described above, then the orientations of the legs, and the position at which the aircraft passes over the SGP could be adjusted. Twin Otter flight speed is about 100 knots (~ 3 km/min) so that the 5 (10) minute legs would be about 15 km (30 km) long.

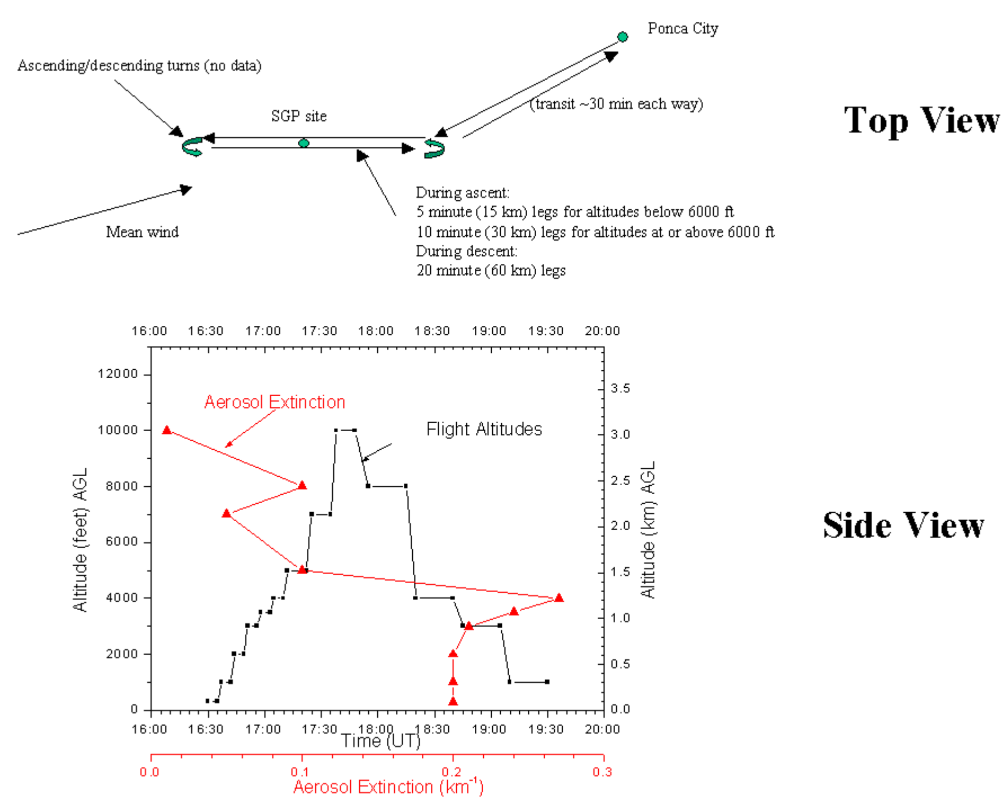

Figure 1b. Top and side views of flight plan 1b.

Experiment 2 – Evaluation of IAP aerosol measurements

Objective(s):

a) evaluate aerosol scattering, absorption, extinction measurements retrieved by instruments on In Situ Aerosol Profiling (IAP) Aircraft
b) evaluate aerosol extinction and optical thickness measurements acquired simultaneously by Raman and MPL lidars, Cimel Sun photometer, MFRSR, airborne Sun photometer, and derived from in situ aerosol scattering, absorption, extinction sensors on aircraft
c) evaluation of vertical variability of aerosol humidification factor

Advocate(s): Ferrare, Ogren, Andrews, Schmid, Redemann

Measurement strategy: This would involve a coordinated flight pattern with the IAP Cessna C-172N aircraft. The IAP aircraft would be the lead aircraft and perform its normal measurement sequence. The Twin Otter would fly in formation and would be the trailing aircraft in this formation. Both aircraft would fly at various altitudes over the SGP facility so that in situ and remote (Sun photometer) instruments on Twin Otter can measure aerosol extinction, scattering, absorption simultaneously with the IAP instruments and with ground-based lidar and surface AOS measurements. Skies should be cloud free or with scattered small Cumulus clouds so that the Sun photometer instruments can measure aerosol optical thickness. Small patchy cirrus clouds are acceptable as long as these clouds do not adversely affect Sun photometer measurements of aerosol optical thickness. These flights should cover both low (AOT<0.1, medium (0.1<AOT<0.3), and high (AOT>0.3) aerosol loading conditions if possible. Flights could occur anytime during daylight hours although preferred times would be during late morning and/early afternoon to coincident with EOS Terra or Aqua overpasses. It would be desirable to launch a sonde at the beginning of the flight (~16 UT) and at the end also (~19-20 UT).

Critical Instruments: IAP, Raman lidar, MPL, AOS scattering/absorption, Cimel Sun photometer, MFRSR, Twin Otter scattering/absorption/extinction measurements

Relevant Instruments/Measurements (See table 1): 1-13, 20-26, 53

Flight Strategy 2:

The Cessna will takeoff first and transit to the SGP vicinity. (~30 min) During this transit the Cessna will climb to 12000 feet. The TO will also takeoff from Ponca city and transit to the SGP vicinity and climb to 12000 feet en route. Both aircraft will perform a series of level leg flights at several altitudes over the SGP site. The Cessna will be the lead aircraft and initiate maneuvers; the TO will trail and will keep a minimum horizontal separation distance of 1000 feet. Both aircraft will maintain an approximate speed of 100 knots. The series of level legs will proceed from 12000 ft (10 min), 10000 ft (10 min), 8000 ft (10 min), 6000 ft (10 min), 5000 ft (5 min), 4000 ft (5 min), 3000 ft (5 min), 2000 ft (5 min), 1500 ft (5 min), 1000 ft (5 min). Both aircraft will then fly another level leg at the altitude of high aerosol scattering/extinction near the top of the boundary layer. The TO scientist will determine this altitude during the flight and communicate this altitude to the Cessna pilot via radio. Upon completion, both aircraft will return to Ponca city airport. With a nominal flight speed of about 100 knots (~ 3 km/min), the 5 (10) minute legs would be about 15 km (30 km) long. Total flight time would be about 03:30.

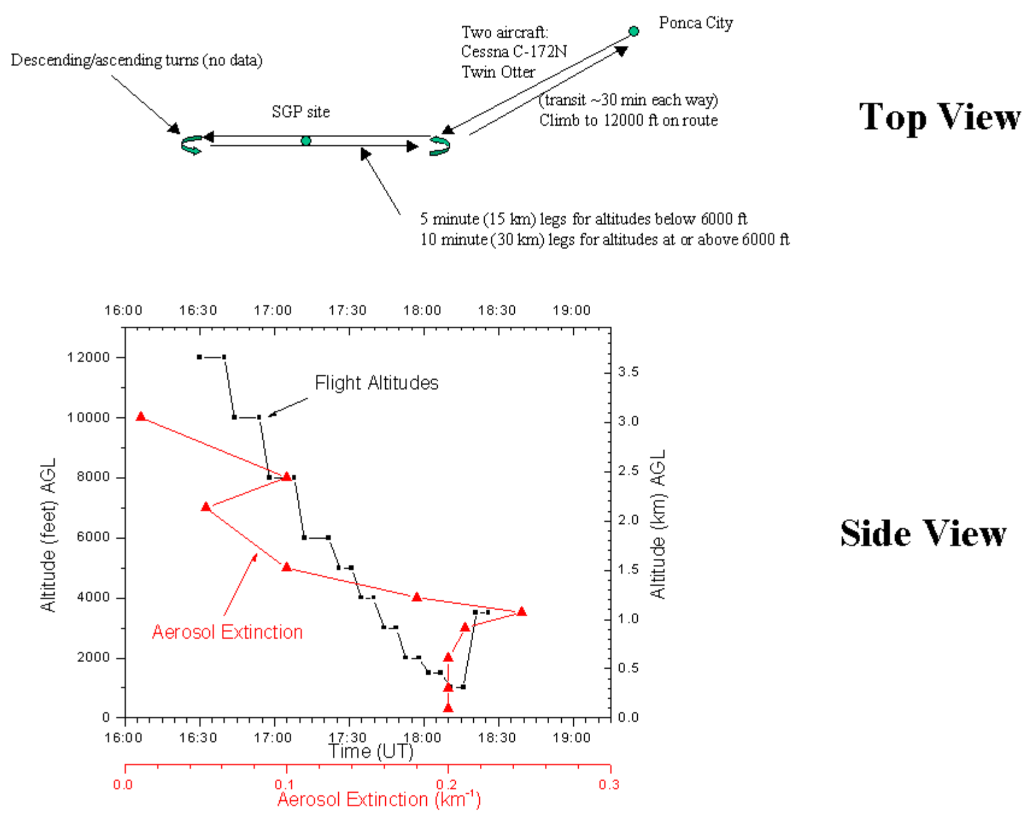

Figure 2. Top and side views of flight plan 2.

Experiment 3 – (a) Layer Absorption Closure - Irradiance closure, (b) In situ absorption closure

Objective(s):

a) Assess the mutual consistency between aerosol-induced flux divergence measurements (derived using airborne flux radiometers) to in situ measurements of aerosol absorption.
b) By combining the airborne flux divergence and AOD measurements, derive a "remotely sensed" aerosol single scattering albedo for comparison with in situ derived single scattering albedo.
c) Evaluate the comparability between the various in situ aerosol absorption sensors.
d) Compare the airborne results of aerosol single scattering albedo to the ground-based retrievals of aerosol properties derived using the SGP AERONET instrument.

Advocates: Schmid, Redemann, Pilewskie, Arnott, Strawa

Fly Twin Otter horizontal legs; one each at the top and at the bottom of the main aerosol layer for flux divergence observations and a subsequent leg near the altitude of maximum aerosol scattering/extinction for in situ observations of aerosol absorption. The goal is to compare measurements and models of diffuse irradiance and flux during low aerosol optical thickness conditions while accurately constraining the aerosol single scattering albedo. First preference is for these flights to occur under low aerosol optical thickness conditions (AOT<0.1) with additional flights under higher aerosol optical thickness conditions. Estimated takeoff time would be around 11 am CDT (16 UT). A radiosonde is normally launched from the SGP site at 1730 UT (12:30 CDT). It would be desirable to launch a sonde at the beginning of the flight (~16 UT) and at the end also (~19-20 UT).

Critical Instruments: Twin Otter radiative flux sensors (SSFR, total flux radiometers), Twin Otter in situ absorption measurements, Twin Otter airborne sunphotometer, ground-based flux radiometers, SGP AERONET instrument

Relevant Instruments/Measurements (See table 1): 1, 5, 8, 9, 12, 20, 24, 40, 43, 44, 47, 53

Flight Strategy 3a (layer absorption closure):
Skies should be cloud free or with relatively constant small cirrus clouds. The Twin Otter will take off from Ponca City and transit to the SGP vicinity (~30 min). TO will then descend to the minimum allowable altitude (~300 feet) and fly a quick ascent profile (or spiral) (~500 feet/minute) to assess the vertical structure of the aerosol field. Maximum altitude of the initial survey ascent should be a location where midvisible AOD from sunphotometer has dropped below 0.05 or the TO ceiling, if former criterion cannot be attained. Assuming a transit altitude of 3,000 ft and a top of the aerosol layer at ~10,000ft, the initial descent/ascent maneuver would take about (26 min.). Alternatively vertical structure information could be relayed to the TO from the ground-based lidar

systems. At the top of the main aerosol layer (as determined by the fast-response in situ aerosol measurements during the initial ascent; here assumed to be about 8000 feet) the TO will fly a horizontal leg for SSFR and integrating flux radiometer measurements centered at SGP for a duration of about (8-10 min.). Twin Otter flight speed is about 100 knots (~ 3 km/min) so that a 10 minute legs would be about 30 km long. After a descent to the maximum of the aerosol layer (assumed here at 5,000 ft), the TO should go back at this altitude (5000 feet) along the same flight track in the heart of the aerosol layer to facilitate in situ observations of aerosol absorption. This would consist of a 10 minute leg, with a 180 degree turn, followed by another 10 minute leg reversing the course. After another descent to an altitude below the aerosol layer or alternatively to the lowest permissible TO altitude (assumed 300 or 500 ft), a final horizontal run for the flux radiometers along the same orientation as the initial flux radiometer run should be performed, again centered at SGP for a duration of 8-10 min. Ascent to cruise altitude (4 min.) and transit back to Ponca City (30 min.) would make this flight plan a short flight. (~02:30). In the case of a distinct two-layered aerosol vertical structure, one additional flux radiometer run (two 10-minute legs with a 180 deg turn in between) between the layers (6000 feet) and one more in situ observation run (two 10-minute legs with a 180 deg turn in between) in the heart of the second layer (7000 feet) could be performed. In this case, total flight time would be about 03:30. In reality, trying to find areas with minimal (or very constant) cloud coverage as required by the flux radiometer method may require significant flight time.

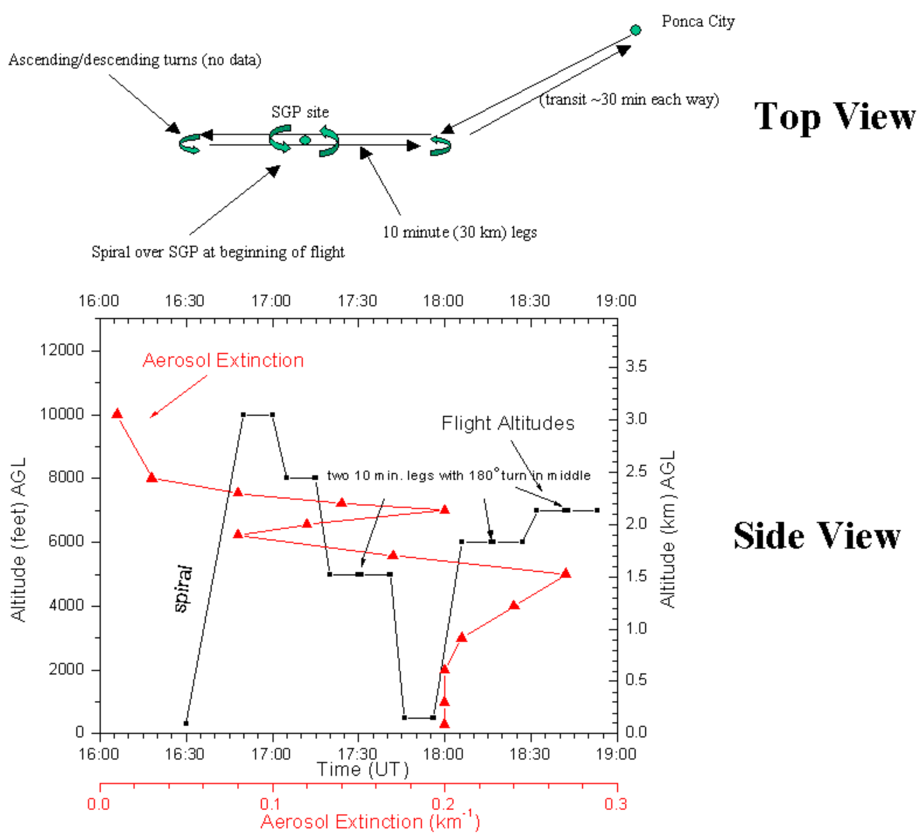

Figure 3a. Top and side views of flight plan 3a.

Flight Strategy 3b (in situ absorption closure):
This experiment does not require cloud free conditions and so can occur when scattered or broken low or high clouds are present. Flights should occur under low, medium, and high aerosol optical thickness conditions. The Twin Otter will take off from Ponca City and transit to the SGP vicinity (~30 min). TO will then descend to the minimum allowable altitude (~300 ft) and fly a quick ascent profile to assess the vertical structure of the aerosol field. Maximum altitude of the initial survey ascent should be a location where midvisible AOD from Sun photometer has fallen off below 0.05 or the TO ceiling, if former criterion cannot be attained. Assuming a transit altitude of 3,000ft and a top of the aerosol layer at ~10,000 ft, the initial descent/ascent maneuver would take about (26 min.). Alternatively vertical structure information could be relayed to the TO from the ground-based lidar systems, although information on the altitude of maximum aerosol absorption needs to come from the aircraft observations. The TO will then fly horizontal L shape patterns. The SGP site should be located under one of these legs. The duration of these patterns should be such that the slowest in situ absorption measurement is still accommodated. Depending on aerosol loading, this should take about 30-40 minutes per L-shape pattern, resulting in two 15-20 minute L-shape legs, which cover about 45-60 km each. If aerosol loadings are small, the length/duration of the L-shape legs may have to be increased. The orientation of L-shape legs relative to the prevailing wind should be such that the in situ measurements are minimally contaminated, i.e., the L-shape legs should both be at a 45 degree angle to the prevailing wind direction. This flight pattern should be repeated at three altitudes at least with sufficient aerosol loading. If an elevated aerosol layer is present, and if time permits, an additional L shaped pattern should be flown at the altitude of this elevated aerosol layer (~7000 feet). Total flight time for a flight including L-shape flight patterns at four altitudes is estimated at ~04:40.

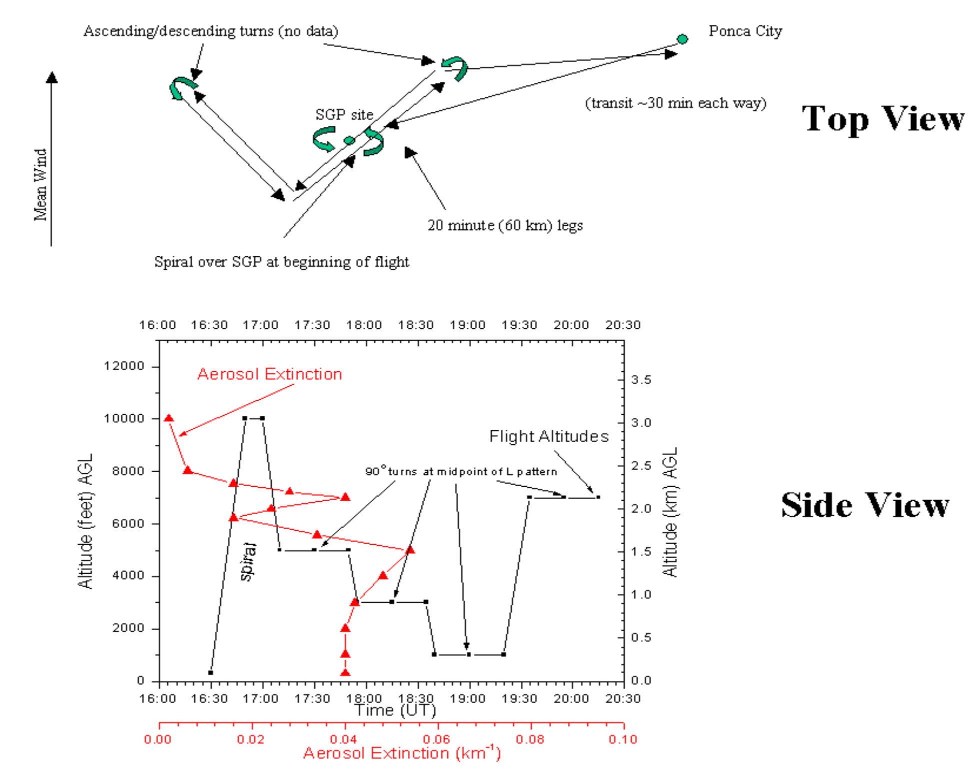

Figure 3b. Top and side views of flight plan 3b.

Experiment 4 – CCN experiment

Objective(s):

a) Investigate relationship between CCN number concentration (at several supersaturations in the range ~0.1 - 1%) and aerosol size distribution, at the surface and at cloud base.
b) Determine whether the cloud nucleating properties of particles just below cloud base be represented using surface measurements of cloud nucleating properties of particles along with profiles of relative humidity and aerosol extinction.
c) Determine relationship between the cloud base CCN number concentrations and size distributions, cloud base turbulence, and cloud droplet number concentrations and size distributions.

Advocate(s): Ghan, Rissman

Measurement Strategy: Use Twin Otter flights at various altitudes within and just above boundary layer to measure vertical variability of CCN concentration, aerosol size distribution, aerosol humidification factor, and aerosol extinction. The measurements will be performed with simultaneous measurements of aerosol extinction and relative humidity by the ground based Raman and MPL lidars. Since the Raman lidar profiles of aerosol extinction, which will be used in the CCN retrieval algorithms, are most sensitive to high aerosol optical thickness conditions, the first preference for these flights is during the daytime when aerosol optical thickness (355 nm) is above 0.15-0.20. There is a desire that these flights occur at various times of the day, in order to contrast well-mixed and stable conditions. It would be desirable to launch a sonde at the beginning of the flight and at the end also. Skies can be clear or cloudy; however, cloud base should be above 2000 feet. The Twin Otter flights will consist of a series of level legs, perpendicular to the mean wind, performed at various altitudes over the SGP site. The majority of these level legs will be performed within the boundary layer. There is a desire to tie the Twin Otter measurements of CCN with the surface measurements of CCN so the minimum flight altitude should be about 300 feet AGL. During clear skies, the maximum altitude will be about 2000 feet above the boundary layer height. During cloudy skies with cloud bases above 1000 feet, then the minimum altitude should also be about 300 feet AGL. Cloud base should be at or above 2000 feet, and below 4000 ft, in order to have sufficient aircraft and lidar sampling below cloud base. During cloudy skies, there should be flight legs just below (~100-200 feet) cloud base, and just above cloud base (~100-200 feet) in order to measure cloud droplet number.

Critical Instruments: Raman lidar, MPL, AOS scattering/absorption, AOS aerosol size distribution, surface CCN measurements, Twin Otter scattering, absorption, extinction, humidification, CCN, aerosol/cloud drop size, liquid water measurements

Relevant Instruments/Measurements (See table 1): 6,8,9,12,18,24, 25,26,27,48,49,50,51,52,53

Flight Strategy 4a (clear skies):

This flight pattern would be used when there are no clouds below about 10000 feet. The TO would takeoff from Ponca City and transit to the SGP vicinity (~30 min). TO will then perform a series of level leg flights at several altitudes oriented perpendicular to the wind direction. These level legs are centered at the SGP site. These flight legs will start at 300 feet (AGL), and proceed to 1000 ft (5 min), 1500 ft (5 min), 2000 ft (5 min), 2500 ft (5 min), 3000 ft (5 min), 3500 ft (5 min), 4000 ft (5 min), 4500 ft (5 min), 5000 ft (5 min), 6000 ft (10 min). Estimated time for climbing turns between legs is 2-3 min. Turns are to be made upwind after each leg. The aircraft will then perform a series of level legs during a descent. These legs would be at the same altitudes as during the ascent and would also be 5 minutes each leg. After completing this portion, the aircraft will return to base on Ponca City. Total flight time is estimated to be 04:00. If the Vance MOA prevents flights perpendicular to the wind direction, then the orientations of the legs, and the position at which the aircraft passes over the SGP could be adjusted. Twin Otter flight speed is about 100 knots (~ 3 km/min) so that the 5 minute legs would be about 15 km long.

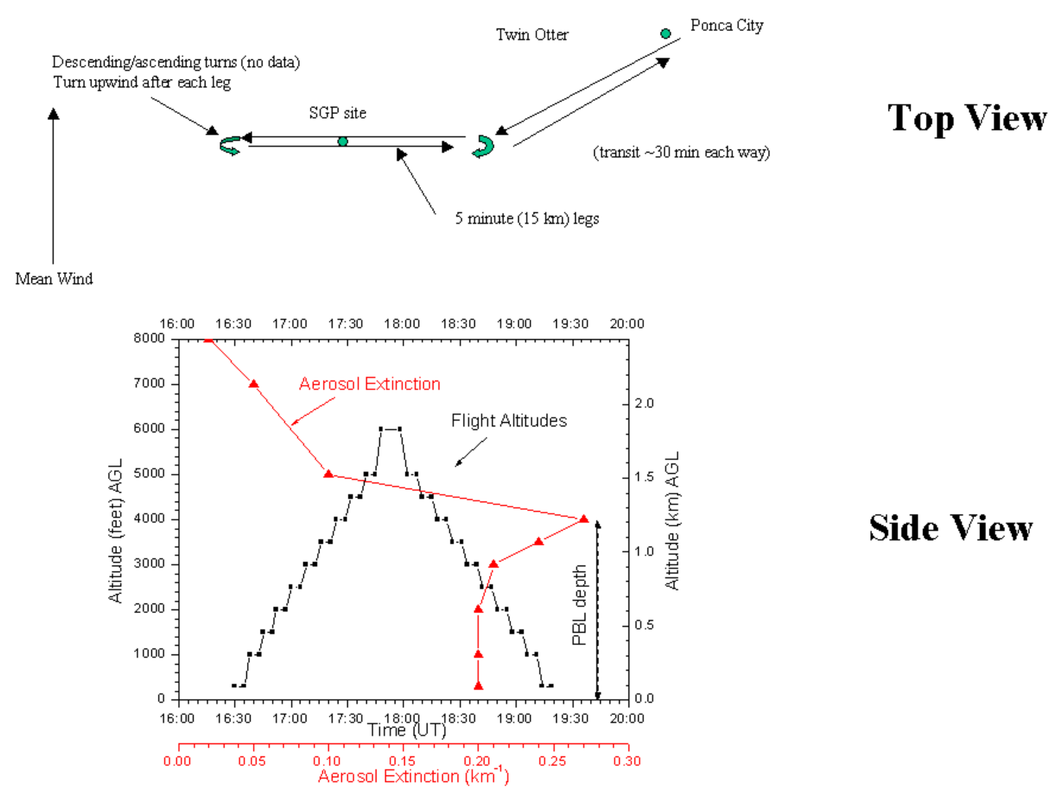

Figure 4a. Top and side views of flight plan 4a.

Flight Strategy 4b (cloudy skies):

This flight pattern would be used when there are low clouds (cloud base between 2000-4000 ft). This pattern is similar to pattern 4a above except that flight legs would be performed at about 200 feet below cloud base, at cloud base, and within the cloud (at 500 and 1000 feet above cloud base.) The TO would takeoff from Ponca City and transit to the SGP vicinity (~30 min). TO will then perform a series of level leg flights at several altitudes oriented perpendicular to the wind direction. These level legs are centered at the SGP site. Assuming the cloud base is at 3500 feet AGL, these flight legs will start at 300 feet (AGL), and proceed to 1500 ft (5 min), 2500 ft (5 min), 3300 ft (5 min), 3500 ft (10 min), 4000 ft (20 min), and 4500 ft (20 min). Estimated time for climbing turns between legs is 2-3 min. Turns are to be made upwind after each leg. Within the cloud (at 4000 and 4500 ft), two 10-min (30 km) legs, separated by a 180 deg turn, would be flown at each altitude. The aircraft will then perform a similar series of level legs during a descent. These legs would be at the same altitudes as during the ascent and would also be 5 minutes each leg. After completing this portion, the aircraft will return to base on Ponca City. Total flight time is estimated to be 04:00. If the Vance MOA prevents flights perpendicular to the wind direction, then the orientations of the legs, and the position at which the aircraft passes over the SGP could be adjusted. Twin Otter flight speed is about 100 knots (~ 3 km/min) so that the 5 minute legs would be about 15 km long.

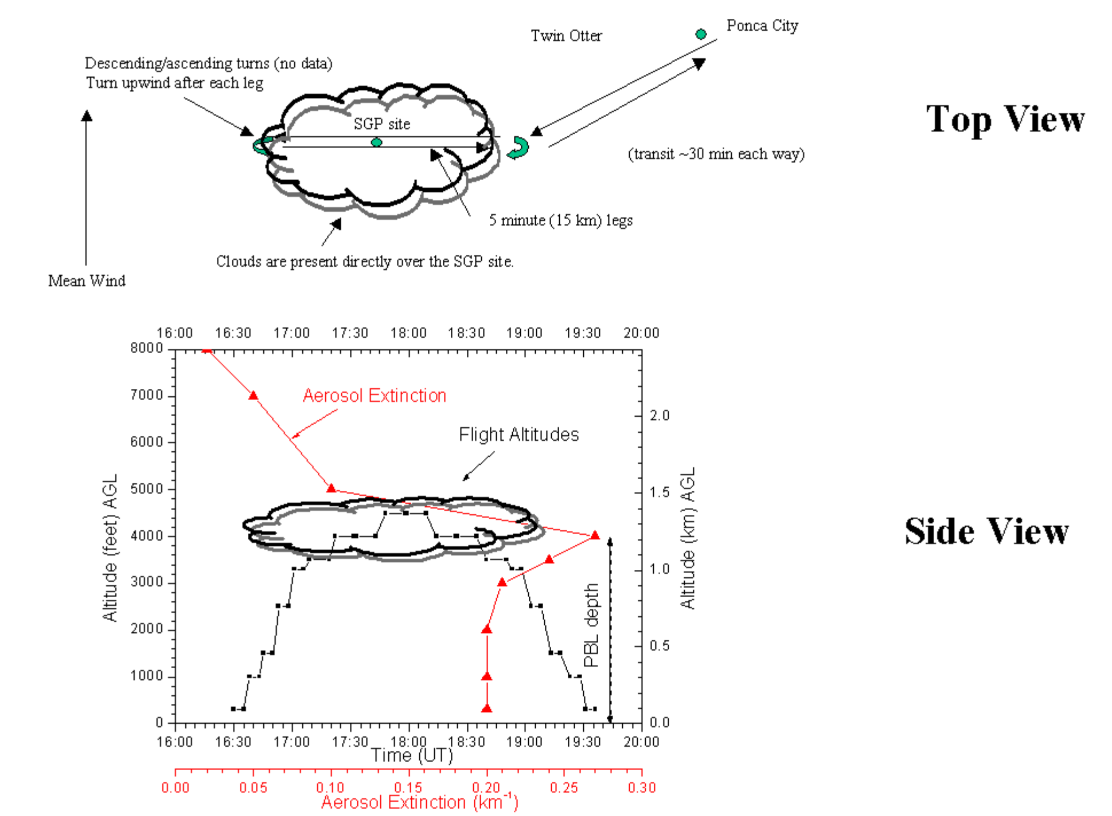

Figure 4b. Top and side views of flight plan 4b.

Experiment 5 – Aerosol Indirect Effect

Objective(s):

a) Investigate the relationship between sub-cloud aerosol parameters, cloud base turbulence, and cloud drop size for clouds with similar amounts of condensed water (liquid water path). Address problem in both a process-oriented sense and a statistical sense by looking at probability distribution functions of subcloud aerosol, turbulence, and cloud drop concentration. [Note, similar goals to Experiment 4, objective c];
b) Evaluate the extent to which subcloud aerosol extinction measured by Raman lidar is an adequate proxy for the aerosol effects on drop size;
c) Evaluate the extent to which ground-based radar remote sensing of cloud drop size is adequate for quantifying the aerosol indirect effect;
d) Evaluate ground-based retrievals of drop size against airborne, downward looking radiance retrievals of drop size.

Advocate: Feingold

Measurement strategy: These flights prefer low overcast (statocumulus conditions) but would be willing to settle for low cloud coverage as low as 20%. It is desirable to contrast scattered cumulus conditions with overcast stratocumulus conditions. The ideal case would be to have these flights occur over the SGP site during cloudy conditions. A second, less desirable option that could be pursued is when clouds are present not directly over the SGP site, but a relatively short (<180 km or < 1 hour) distance away from Ponca City and the SGP site. The flight strategies for these two cases are described below. There is no preference for the time of day for these flights, although the required presence of cumulus or stratocumulus suggests that these flights would most likely occur late morning or afternoon. It would be desirable to launch a sonde at the beginning of the flight and also at the end.

Critical Instruments:
Surface-based: Raman lidar, MMCR radar, microwave radiometer, accumulation mode aerosol size distribution, CCN, *f*(RH), state parameters;
Airborne (Twin Otter): CCN, aerosol size distribution, aerosol composition (or proxies such as absorption, scattering, humidification factor), drop size distribution, liquid water content, gust probe (updraft, turbulence), radiances for downward-looking retrieval of drop size, state parameters.

Relevant Instruments/Measurements (see table 1):

Twin Otter: 1, 5, 7, 8, 9, 12, 14, 15, 18, 20, 27, 43, 49, 50, 51, 52, 53
Surface: MMCR, MWR, 2, 6, 11, 13, 16, 17, 19, 21, 22, 24, 25, 28, 29, 30, 31, 32, 33, 34, 35, 48

Flight Strategy:

For both scenarios below, the target cloud conditions are shallow, nonprecipitating boundary layer clouds with cloud tops at or below 7000 feet. These clouds can be either cumulus or stratocumulus where soundings indicate convective activity. The cloud base height must be greater that the minimum allowed flight altitude. The flight levels indicated in the scenarios below can be adjusted according to cloud base and cloud top heights. The lowest leg should be as low as permissible and preferrably in a region where the relative humidity is below 70%. Flight legs should be flown at about 1500 and 500 feet below cloud base. Legs should also flown at 300 ft above cloud base, 1000 feet above cloud base and/or 300 feet below cloud top, and at about 1000 feet above cloud top. This top altitude is for designed for downward looking TO retrievals of drop size and measurement of reflectance. The scenarios below assume a cloud base of 3500 feet and a cloud top of 5000 feet.

Flight Strategy 5a (*Cloudy conditions at SGP):*

Focused overflights of the SGP central facility during cloudy conditions to avail ourselves of the ground-based remote sensors. The Twin Otter would takeoff from Ponca City and transit to the SGP vicinity (~30 min). TO will then perform a series of level leg flights at several altitudes oriented perpendicular to the wind direction. These level legs are centered at the SGP site. The TO would fly level legs at 1000 ft (10 min), 3000 ft (10 min), 3800 ft (25 min), and 4500 ft (25 min), 6000 ft (20 min). Time permitting, this pattern would then proceed downward, with legs at 4500 ft (25 min), 3800 ft (25 min), 3000 ft (10 min), and 1000 ft (10 min). If time does not permit, the descent pattern would fly legs at 4500 ft (15 min), 3800 ft (15 min), 3000 ft (10 min), and 1000 ft (10 min). In order to keep legs at 15 km (~5 min) length to maximize overpasses of central facility, and to keep the preferred leg orientation of perpendicular to the mean wind, 180 degree turns would be executed at the end of each 5 minute leg. Turns are either level, ascending, or descending (after 6000 ft leg). Turn upwind. Total flight time would be about 04:50.

Flight Strategy 5b (*Cloudy conditions in the vicinity of but not directly above SGP):*

This pattern would be very similar to the pattern described above, except that the legs would not be flown directly over the SGP site but rather at the location of the clouds. Here the assumed transit time would be longer (up to 1 hour each way) so that the time allotted for the level legs would be shortened to keep total flight time within the Twin Otter retraints. The TO would take off from Ponca City and transit to the location of clouds (< 60 min). TO will then perform a series of level leg flights at several altitudes oriented perpendicular to the wind direction. The TO would fly level legs at 1000 ft (10 min), 3000 ft (10 min), 3800 ft (30 min), and 4500 ft (30 min). This pattern would then proceed downward, with legs at 3800 ft (30 min), 3000 ft (10 min), and 1000 ft (10 min). In this case the legs would be 30 km (~10 min) in length. In order to keep the preferred leg orientation perpendicular to the mean wind, 180 degree turns would be executed at the end of each 10 minute leg. Turns are either level, ascending, or descending (after 4500 ft leg). Turn upwind. Total flight time would be about 04:45.

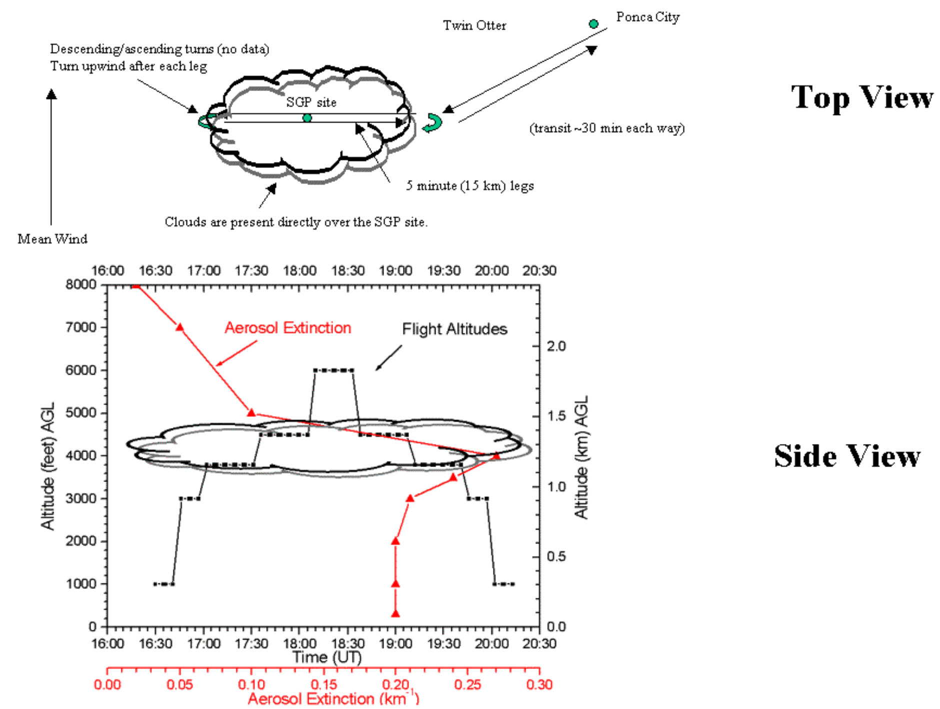

Figure 5a. Top and side views of flight plan 5a.

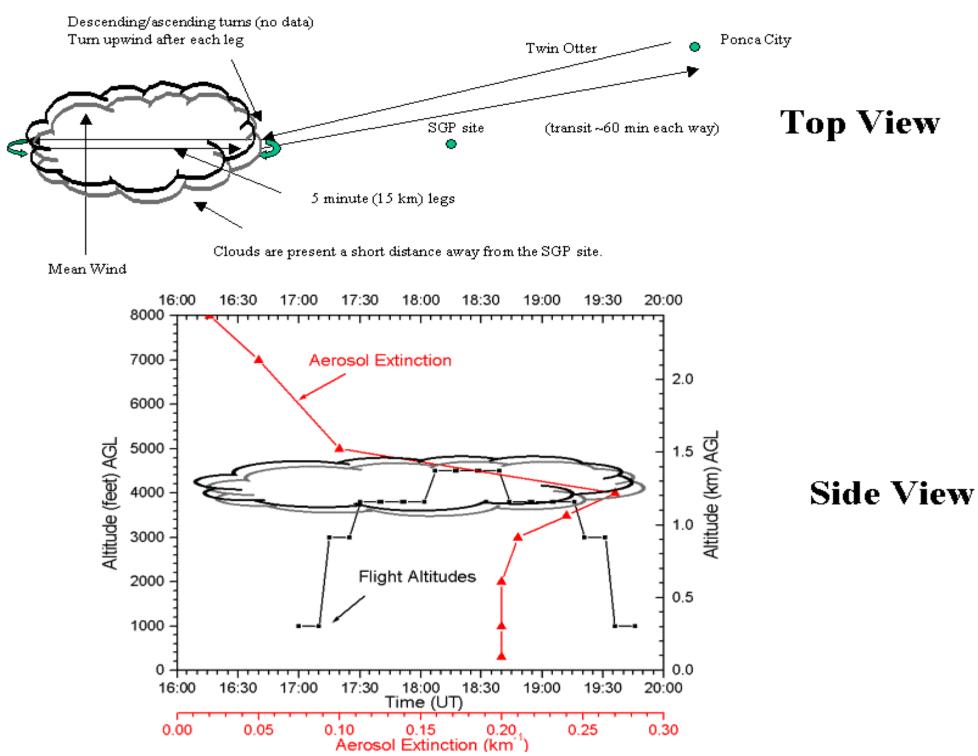

Figure 5b. Top and side views of flight plan 5b.

Experiment 6 – Spatial aerosol variability flights

Objective(s):

a) Assess satellite sub-pixel/scene variability in aerosol optical depth to determine how representative the SGP site point observations are for a larger scene.
b) Validate over-land aerosol optical depth retrievals of various satellite sensors, including MODIS, MISR, etc. and investigate the mutual consistency between suborbital and space-based assessments of aerosol variability.
c) Determine vertical distribution of aerosol extinction and particle types to validate aerosol models that are used in or retrieved from satellite sensor data inversion.

Advocates: Schmid, Redemann, Ferrare, Alexandrov

Measurement Strategy:

Fly a TO profile to assess vertical distribution of aerosol extinction near satellite overpass time. Fly low-level Twin Otter horizontal legs between MFRSR sites to assess spatial variability in aerosol optical depth around satellite overpass time. Fly 1-2 horizontal legs at various altitudes to assess particle size distribution and type (chemical composition) around satellite overpass. The six (6) MISR local mode observations for SGP (#009 SGP-Lamont, 36.605N, -97.485W) during the month of May 2003 are May 06 (17:28UT), May 08 (17:16UT), May 15 (17:22UT), May 22 (17:28UT), May 24 (17:16UT) and May 31 (17:22UT). There are about 20 Terra overpasses suitable for MODIS validation. Both predictions likely will change due to satellite maneuvers between now and the IOP. However, the general number of validation opportunities and the approximate Terra overpass time between 16:30 and 17:30UT will still be correct. A similar number of Aqua MODIS validation opportunities will arise. If there is suitable interest, there could be validation opportunities for CERES derived flux measurements. These flights should occur under generally cloud free skies to maximize airborne Sun photometer measurements of aerosol optical thickness.

Critical Instruments: Twin Otter airborne sunphotometer, Twin Otter in situ extinction/absorption measurements, Twin Otter radiative flux sensors, Twin Otter aerosol size distribution and chemical composition samplers, MFRSR at central facility and at selected extended facilities, Cimel Sun photometer, Raman and MPL lidars, AOS system

Relevant Instruments/Measurements (See table 1): 1, 5, 8, 9, 12, 14, 15, 18, 20, 21, 22, 24, 25, 26, 27, 43, 44, 47, 53

Flight Strategy:
There are two scenarios listed. The first describes flight legs over the MFRSR generally north of the SGP site, and the second describes legs generally south of the site. The particular pattern chosen will depend upon anticipated cloud and aerosol conditions, flight clearances, etc.

Flight Strategy 6a (northern):
The Twin Otter will take off from Ponca City (map reference 1) and transit to the SGP vicinity (map reference 2) (~30 min). TO will then ascend to maximum attainable altitude (~12000 ft) and fly a 500ft/min descent profile to minimum allowable altitude (~300-500 ft) over the SGP CART site. Assuming a transit altitude of 5,000 ft and a top of the profile at ~12,000 ft, the initial ascent/descent maneuver would take about (30 min.). The Twin Otter will then fly two 10 minute (~30 km) low level passes centered over the SGP site. It would be best to time the low-level flight leg in such a way that the TO is in the closest possible proximity to the SGP site at exact satellite overpass time. These legs should generally be oriented north to south, which is generally the orientation of the transit to and from the extended facilities. Each pass is separated by a 180 deg turn. The Twin Otter will then perform a climbing ascent to an altitude near the top of the boundary layer (assumed here to be about 5000 ft), where the maximum aerosol scattering/extinction was observed during the previous descent. The TO will then fly two 10 min (~30 km) legs at this altitude along the same line as the previous horizontal leg. If an elevated (above boundary layer) aerosol layer was observed during the initial descent, then the TO will then perform a climbing ascent to this altitude (here assumed to be about 7000 ft) and fly two additional 10 min (~30 km) legs along the same line as the previous. (If no significant elevated aerosol layers were observed, then the TO would proceed to extended facility EF-9 (map reference 3)). The TO will then descent to the lowest possible altitude (500-1000 ft) permitted to transit among the various sites, and the travel to extended facility EF-9 (map reference 3) (~15 min, 45 km), then to EF-5 (70 km, 23 min) (map 4), then to EF-2 (60 km, 20 min) (map 5), then to EF-4 (100 km, 33 min) (map 6), then to the central facility (120 km, 40 min) (map 7), then to EF-12 (80 km, 27 min) (map 8), then return to base at Ponca City. Each time the TO flies over facility, it should fly straight and level for at least 1 minute after flying over the facility before turning to go on to the next point. Given a typical satellite overpass time of 17:00UT (12:00CDT), the TO would have to depart Ponca City at about 16:00UT (11:00CDT) to accommodate the coordination of this flight plan with satellite overpass time. Total TO flight time is estimated to be ~ 05:00 min. Note that TO will fly over or close by Wichita, KS when flying between EF-9 and EF-5 (map 3 and 4). It is desired that the aircraft fly as close to city as possible to investigate urban impact on aerosol extinction and optical thickness. In addition, it is desired that the TO fly over or near the Sooner power plant (36.45N, 97.05W) during transit between CF and EF-12 or before returning to base. This plant may be a significant source of pollution transport to the CF.

Flight Strategy 6b (southern):
The Twin Otter will take off from Ponca City (map reference 1) and transit to the SGP vicinity (map reference 2) (~30 min). TO will then ascend to maximum attainable altitude (~12000 ft) and fly a 500ft/min descent profile to minimum allowable altitude (~300-500 ft) over the SGP CART site. Assuming a transit altitude of 5,000ft and a top of the profile at ~12,000ft, the initial ascent/descent maneuver would take about (30 min.). The Twin Otter will then fly two 10 minute (~30 km) low level passes centered over the SGP site. It would be best to time the low-level flight leg in such a way that the TO is in the closest possible proximity to the SGP site at exact satellite overpass time. These legs should generally be oriented northeast to southwest, which is generally the orientation of the

transit to and from the extended facilities. Each pass is separated by a 180 deg turn. The Twin Otter will then perform a climbing ascent to an altitude near the top of the boundary layer (assumed here to be about 5000 ft), where the maximum aerosol scattering/extinction was observed during the previous descent. The TO will then fly two 10 min (~30 km) legs at this altitude along the same line as the previous horizontal leg. If an elevated (above boundary layer) aerosol layer was observed during the initial descent, then the TO will then perform a climbing ascent to this altitude (here assumed to be about 7000 ft) and fly two additional 10 min (~30 km) legs along the same line as the previous. (If no significant elevated aerosol layers were observed, then the TO would proceed to extended facility EF-19 (map reference 3)). The TO will then descend to the lowest possible altitude (500-1000 ft) permitted to transit among the various sites, and then travel to extended facility EF-19 (map reference 3) (~37 min, 112 km), then to EF-20 (85 km, 28 min) (map 4), then to EF-18 (70 km, 23 min) (map 5), then to EF-12 (112 km, 37 min) (map 6), then to the central facility (80 km, 27 min) (map 7) then return to base at Ponca City. Each time the TO flies over facility, it should fly straight and level for at least 1 minute after flying over the facility before turning to go on to the next point. Given a typical satellite overpass time of 17:00UT (12:00CDT), the TO would have to depart Ponca City at about 16:00UT (11:00CDT) to accommodate the coordination of this flight plan with satellite overpass time. Total TO flight time is estimated to be ~05:00. Note that TO will fly over or close by Oklahoma City, OK when flying between EF-19 and EF-20 (map 3 and 4). It is desired that the aircraft fly as close to city as possible to investigate urban impact on aerosol extinction and optical thickness. In addition, it is desired that the TO fly over or near the Sooner power plant (36.45N, 97.05W) during transit between Cf and EF-12 or before returning to base. This plant may be a significant source of pollution transport to the CF. In addition, it is desired that the TO fly over or near the Sooner power plant (36.45N, 97.05W) during transit between d EF-12 and CF or before returning to base. This plant may be a significant source of pollution transport to the CF.

Top View

Side View

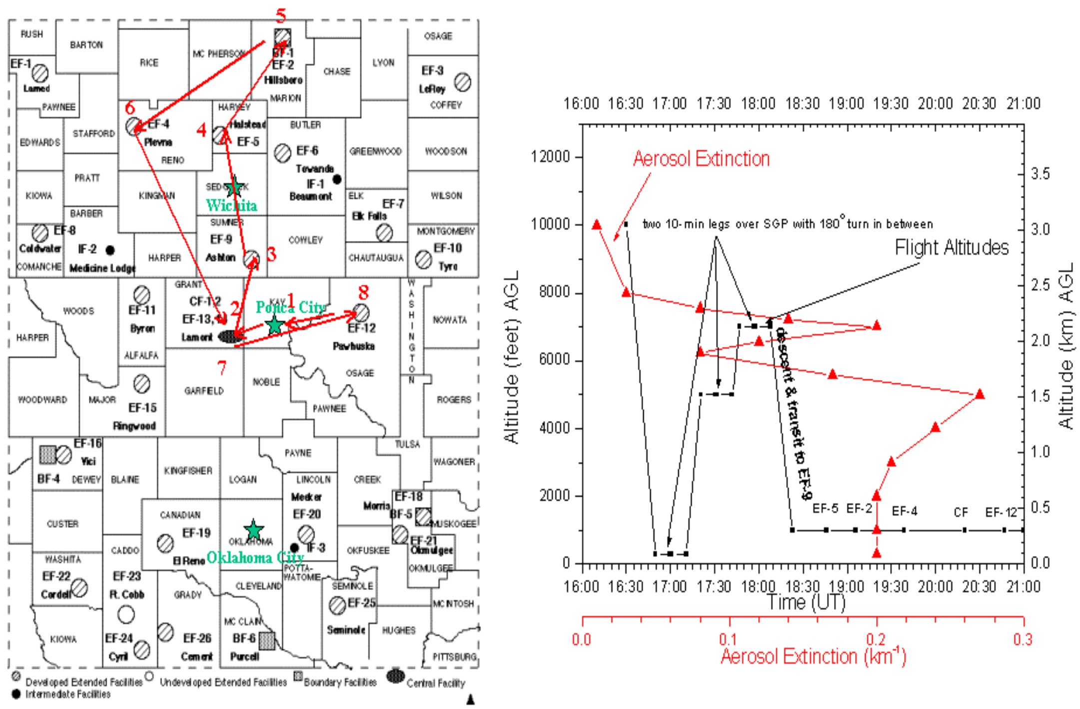

Figure 6a. Top and side views of flight plan 6a.

Top View

Side View

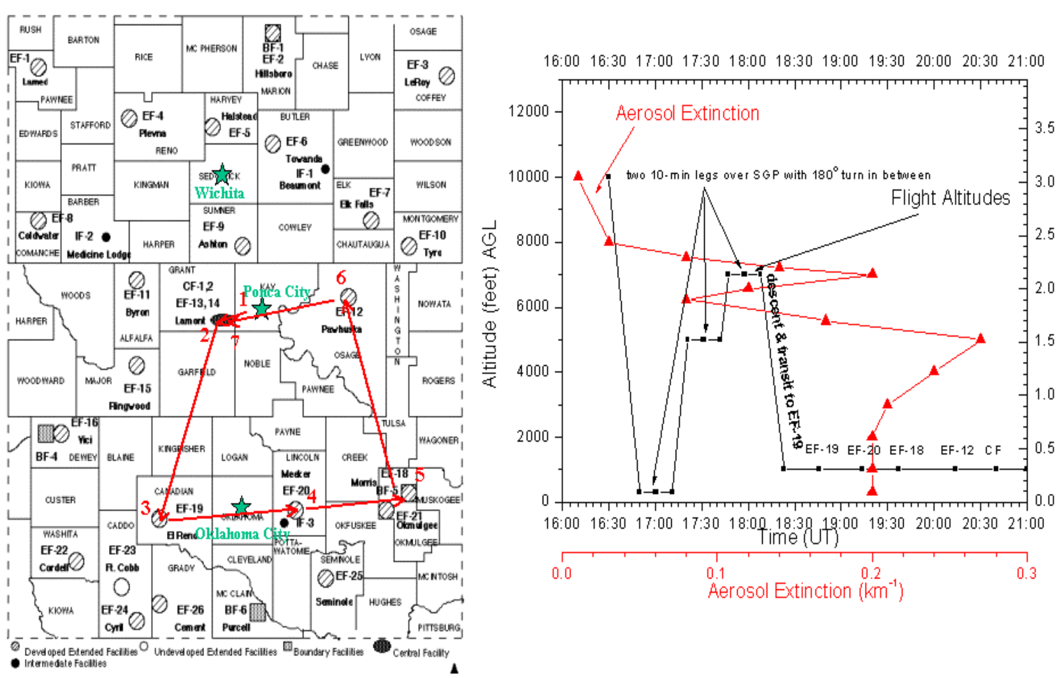

Figure 6b. Top and side views of flight plan 6b.

Allocation of Flight hours

There are 60 hours total available for science flights. Of this total, about 40 would be available for aerosol related studies, and about 20 for cloud indirect/CCN studies. Since some of the flight patterns are similar (e.g. 1b and 3b; 4a, 1a, 1b), there is considerable overlap in achieving the science goals, so that a combination of these patterns would be similar to repeating the same pattern more than once.

Estimated breakdown:

Experiment #	Experiment	Hours/flight	# flights	Flight hours
2	Evaluation of IAP	3.5	3	10.5
3a	Layer absorption/Irradiance closure	3.5	2	7
1b	Raman, MPL evaluation/slow extinction closure	4	1	4
3b	In situ absorption closure	4	1	4
1a or 4a	Raman, MPL evaluation/fast extinction closure	4.33	1	4.33
1b or 3b or 4a	Lidar evaluation/absorption closure	4	1	4
6a or 6b	Spatial aerosol variability	5	1	5
			Subtotal:	39
4b	CCN (cloudy)	4	3	12
5a or 5b	Cloud indirect (cloudy)	4.75	2	9.5
			Subtotal:	21.5
			Grand Total:	60.5